Some Background to the Absolute-Relational Debate

Gordon Belot

Department of Philosophy
University of Pittsburgh

It is traditional to approach the absolute-relational debate about the nature of space and motion via the views of Newton and Leibniz. And, of course, since their views developed against the backdrop of Cartesian physics, it is often helpful to keep this in mind when approaching their writings on these subjects.

Many treatments of the history of the debate in the literature on the philosophy of space and time begin with these three figures. In briefest outline, the story runs as follows. (1) Descartes defined the place of a body via its relations to its immediate neighbours and motion as change of place so-conceived. He attempted to base upon this notion a mechanistic physics governed by rules of impact and the principle of inertia. The result was a disappointing mess. (2) Newton defined the state of motion of a body as its motion relative to absolute space—the latter he thought of as a non-material existent, neither substance nor accident, consisting of parts that maintain their identity through time. This provided the conceptual underpinnings for his laws of motion. The result was a resounding success. (3) Leibniz's criticisms of Descartes's and Newton's accounts of space and motion have exercised a considerable influence on natural philosophical discussions down to the present day. But his attempts at constructing a systematic and credible competitor to the physics of his rivals never came to fruition—in part, it seems, because Leibniz was pulled in several contradictory directions by his critical intuitions. In particular, it is hard to see how to fit together his relational account of space (which would seem to undercut any notion of absolute motion) with his views about force (which would appear to ground absolute notions of motion).

Of course, philosophical debates about the nature of motion and space began long before the 17th century. Indeed, the views of Descartes and Newton are closely related to certain ancient views. And in antiquity, through the middle ages, and down to the 17th century, one finds many arguments for and against these views, including precursors of some of the arguments that figured in the Leibniz–Clarke correspondence, and which still drive much of the philosophy of space and time. All of this is well-known historians of these periods, but is less widely-appreciated among philosophers of space and time. In these notes, I hope to remedy this situation a bit, by providing a sketch some of this earlier history. In the concluding section I make some remarks about what was genuinely novel to the 17th century context.

***

The natural place to begin is with Aristotle. In Aristotle the finite material world is organized into a spherical cosmos. The Earth sits at rest at the centre of this cosmos; above the atmosphere, are a series of nested spheres rotating about the Earth; the Moon, Sun, planets, and stars are fixed to these spheres; and the composition of the circular motions of these spheres gives rise to the motions of the heavenly bodies through the sky.

The matter of the Aristotelian cosmos forms a plenum. Thus every body is surrounded by matter; this allows Aristotle to take the place of a body to be "the boundary of the containing body at which it is in contact with the contained body" (*Physics* IV.4, 212a5–7).[1] Or at least, this works for bodies in the interior of the cosmos: "the heaven … is not anywhere as a whole, nor in any place, if at least, as we must

[1] All translations of Aristotle from McKeon (ed.) (1941).

suppose, no body contains it” (212a8–10). We nonetheless say that the outermost sphere of the heavens—the sphere of the fixed stars—completes one revolution each day.[2]

Aristotle had to contend with atomists, who claimed that movement would be impossible in a plenum and posited a cosmology involving infinitely many atoms moving through an infinite void. To the atomists’ claim about the impossibility of motion in a plenum, Aristotle retorted, reasonably enough, that “not even movement in respect of place involves a void; for bodies may simultaneously make room for one another, though there is no interval separate and apart from the bodies that are in movement. And this is plain even in the rotation of continuous things, as in that of liquids” (*Physics*, IV.7 214a28–32).

Aristotle also provides positive arguments against the possibility of a void—not only is there no space empty of matter within the cosmos, but the cosmos itself is not to be thought of as immersed in a larger void space.

(1) In *De Caelo*, void is characterized as “that in which the presence of body, though not actual, is possible” (I.9 279a14–15). But it is not possible for there to be matter beyond the cosmos: such matter could not be there naturally, for the natural place of earth, water, air, fire, and the heavenly material is within the cosmos; nor could it have gotten there by violence, for in that case it would have to be located in the natural place of some other matter—and there is none such. So an extra-cosmic void is impossible.[3] The same argument is supposed to show that there can be no other worlds located outside of our own.

---

[2] I believe that we are supposed to reach this conclusion by regarding the Earth as fixed, then examining the relative motion between each of the surrounding spheres; see Sorabji (1988, 193–196) for discussion of ancient reactions.

[3] There is some reason to think that that Aristotle here assumes that something is possible only if it happens at some time or other; see Hahm (1977, 103 especially fn. 32).

(2) In the *Physics*, Aristotle tells us that the partisans of the void regard "it as a sort of place or vessel which is supposed to be 'full' when it holds the bulk of which it is capable of containing, 'void' when it is deprived of that—as if 'void,' and 'full' and 'place' denoted the same thing, though the essence of the three is different" (IV.6 213a15–20). Aristotle offers a series of objections to the void in Book IV, Chapter 8, showing that a body immersed in a void would be both motionless and move with an infinite velocity, etc. These arguments turn upon the details of the Aristotelian account of natural place, motion through resisting media, etc., and they exercised a considerable influence on medieval discussions of the possibility and nature of motion in a void (see Grant 1981a, Chapter 3)—but they need not concern us here. To these we can add the following remark that occurs in the preamble to Aristotle's discussion of place: "place cannot be body; for if it were there would be two bodies in the same place" (*Physics*, IV.1 209a6–7; see also IV.8 216a34–b10). Many of Aristotle's medieval successors saw here a powerful consideration against the possibility of the void. For if the void is conceived of as a sort of three-dimensional entity capable of being filled by body, then we must accept that when it is so filled, we have two things existing in the same place—an absurdity.[4]

***

Now, these views of Aristotle were subject to trenchant criticism throughout antiquity, among the scholastics, and in the early modern period. Let me begin by noting three anti-Aristotelian arguments which are of special concern for our purposes. (These are chosen because they were influential from antiquity through the 17th century; no claim is made that they provide even a fair sample of historical arguments.)

[4] For the medieval influence of this argument, see Grant (1981a, e.g., 32 ff.).

(1) *Paradoxes of Aristotelian Motion*. If, as is natural, (local) movement is understood as change of place, then the Aristotelian definition of place leads to counter-intuitive consequences: a body such as a tower moves (because air surrounding it constantly circulates); similarly, bodies can approach one another even if neither moves. These observations provide an argument against the Aristotelian accounts of place and local motion.

(2) *Arguments from Cosmic Size and Shape*. Presumably the cosmos does or could change shape, or could have been a different size or shape—and this seems to suggest that there must be void outside of the cosmos in order to make this so.

(3) *Arguments from Possible Motions*. Our intuitions recognize the possible states of motions which must be understood as motion relative to the parts of a separately existing void—no account of motion in terms of the relations between material parts will suffice. This provides another sort of argument in favour of the void.

***

I will make some remarks about the history of each of these families of objections, beginning with the Paradoxes of Aristotelian Motion.

Under this heading we find arguments directed against the Aristotelian definition of place. They appear to have first emerged in the writings of Aristotle's immediate successor, Theophrastus (see Sorabji 1988, Chapter 11), and to have played some role in the rejection by the Aristotelian majority in antiquity of Aristotle's conception of the place of a body as the boundary of the surrounding bodies (on this see Sorabji 1988, 199–201). In the middle ages, when Aristotle's account of place was widely accepted (Grant 1976, 154), these paradoxes were rediscovered and widely discussed (Grant

1981a, 125; 1981b, ß2). In the 17th century, they were available even to non-scholastic philosophers in, e.g., the *Physiologia Epicuro-Gassendo-Charltoniana* of Walter Charleton (p. 69).[5]

It is clear that these arguments create difficulties for Aristotle. He affirms in his *Physics* that: "It is always with respect to substance or to quantity or to quality or to place that what changes changes" (200b33–34); and later he is quite specific in identifying locomotion with change of place (260a27–28). And so it seems clear that he regards a body as moving (in our sense) if and only if there is a change along its immediate boundary. And so, prima facie, it seems that a boat moored in a strong current will count as moving, while one drifting downstream along with the current may count as at rest (depending what whether we require the individual parts of water along its surface to be at rest, and whether they in fact are).

Now, it isn't clear whether the charge in this form will stick. At one point Aristotle departs from his original characterization of the motion of a body in terms of what is happening at the immediate boundary of the body and maintains instead that: "when what is within a thing which is moved, is moved and changes its place, as a boat on a river, what contains plays the part of a vessel rather than of place. Place on the other hand is rather what is motionless: so it is rather the whole river that is place, because as a whole it is motionless. Hence we conclude that the *innermost motionless boundary **of** what contains is place*" (212a15–19). Here is Burnyeat's influential reading:

The point of the refinement is this: the place of X was to be the boundary of Y enclosing X, but if Y is moving, this specifies a carrier or vessel of X rather than X's place …. The solution is to find

[5] This last work is of interest in part because Newton is known to have read it carefully as an undergraduate (Westfall 1962, 172, especially fn. 5). It is an eccentrically augmented free translation of a work by Gassendi—and it played a pivotal role in making available in English Gassendi's attempts to Christianize and modernize atomism.

Z such that Z is static and Z encloses X at the same boundary as Y does. Example: X=a boat, Y=the body of water flowing in the Cayster, Z=the river Cayster as a geographical entity. (1997, 102 n. 15)

There is a question of coherence here. Our system of judgments about place and motion will be founded upon an initial choice of a body which counts as motionless. Considering a different body as motionless at the beginning would result in different judgments about place and motion. Now in Aristotle's scheme, it is clearly safe to count the Earth as motionless, and to work outwards from there. But then place is specified by position relative to the surface of the Earth, and motion by change of distance with respect to reference points on the surface of the Earth. So Aristotle's attempt to shore up his definitions of place and motion lead quickly to them being superseded by quite different ones. Indeed, one strand of Scholastic thought followed this course (Grant 1981b, §3), referring motion ultimately to change of a body's relation to the immobile centre and poles of the cosmic sphere (presumably it went unnoticed that a body moving along the equator of the cosmic sphere would count as immobile under this criterion).

***

Now turn we to the positive arguments offered by proponents of the void—the arguments from cosmic size and shape and the arguments from cosmic motion. Here it is convenient to discuss both arguments together, moving from one group of commentators to the next.

THE ATOMISTS. The atomist cosmology featured an infinite number of indivisible particles moving in an infinite void. Our cosmos formed by chance, and will eventually decay—it is one of an infinite number of *cosmoi*.

Against the finite spherical universe of Aristotle, Lucretius deploys (*De Rerum Natura*, I.968–983) an argument attributed by ancient authors to Archytas (contemporary of Plato and teacher of Eudoxus): if you are situated at the edge of the cosmos, what happens if you extend your staff (or spear, or sword, …) beyond the edge? If there is something there to prevent its extension, then you were not yet at the edge—there is further matter. On the other hand, if you are successful, then there must be receptive void. Repeating the argument whenever a new putative boundary is reached shows that there is infinite extension—of either matter or void.[6]

Lucretius also gives two detailed arguments in favour of the void, defined as "intangible empty space" (I.334).[7] The first rests upon the traditional atomist contention that motion would be impossible in a plenum.[8] The second, cleaned up and amplified, proceeds thus: suppose two bodies in contact along a surface move away from one another; then air must fill the space between the surfaces initially in contact; but if it moves with only finite velocity, there will be void immediately after the separation of the bodies.[9] Following this discussion, Lucretius remarks that:

> *If there were no place and space, which we call void,*
> *Bodies could not be situated anywhere*
> *And they would totally lack the power of movement*
> *As I explained a little while ago.*[10]

---

[6] For discussion of origins of this argument and of Aristotelian responses in antiquity, see Sorabji (1988, 125–128). For Scholastic responses, see Grant (1981a, 106–108). The argument also appears in More (Koyré 1957, 123) and Gassendi (Grant 1981a, 389 n. 168). Here is another popular atomist argument: that which is limited must be limited by something (Epicurus, *Letter to Herodotus*, 41; Lucretius, *De Rerum Natura,* I.957–965);
on this see Sorabji (1988, 136–138) and Grant (1981a).

[7] All quotations of Lucretius from Melville (trans.) (1997).

[8] *De Rerum Natura*, I.335-345 and I.370-383. See also Epicurus, *Letter to Herodotus*, 40. Note Aristotle's response, *Physics*, IV.7 214a28–32. See Charelton, *Physiologia*, 19. Note: the undergraduate Newton appears to have accepted this argument; Westfall (1962, 174).

[9] *De Rerum Natura*, I.384-389. See Grant (1981a, §4.E) for Scholastic responses to this sort of challenge.

[10] I.418-421. See also Epicurus, *Letter to Herodotus*, 40: "And if there did not exist that which we call void and space and intangible nature, bodies would have no place to be in or move through, as they obviously do move" (translation of Inwood and Gerson 1994).

Now, he *has* earlier told us how bodies could not move if there were no void. But that they would be situated nowhere is a new thought, and one on which he never really elaborates. I do not think it much of a stretch to think of Lucretius as taking for granted something like absolute space here: his void, as an infinite three-dimensional non-corporeal entity provides a standard of place and movement for bodies—a body changes place if it occupies a new portion of void and the state of motion of a body is referred to its change of place in the void.

Indeed, it is not easy to see how we can otherwise make sense of certain characteristic atomist theses. At least from Epicurus onward, atomists held that the void has a natural distinguished direction, *downwards*, and that the natural motion of atoms is downwards, with atoms of all sizes moving at the same speed.[11] In Lucretius (and, according to ancient authorities, in Epicurus as well—see Inwood and Gerson (eds.) (1994, 47)) we find that this natural motion is sporadically interrupted by the mysterious swerve which puts atoms on collision courses; these collisions are ultimately responsible for the formation of cosmic vortices. As Lucretius notes, without the swerve, the atoms

Would fall like drops of rain through the void.
There would be no collisions, no impacts
Of atoms upon atom, so that nature
Would never have created anything. (I.222–225)

The most obvious way for us to make sense of this is to refer the motion of atoms to the parts of the void, conceived of as retaining their identity over time. For if we look at the relations between the atoms in the swerveless atomist universe, we find them utterly static—and we would have no reason to maintain that the atoms were falling down like drops of rain rather than sitting motionless.

[11] See Furley (1987, Chapters 9 and 10) for discussion of pre-Epicurean atomism.

THE STOICS. The Stoics, while accepting a spherical and void-free cosmos, explicitly located it within an infinite void (see, e.g., Hahn 1977, 103–107). Now, the Stoics more or less accept Aristotle's terms—void is that which is capable of being occupied by matter, but is not so occupied. But in favour of the void they offer arguments of the sort that we are interested in.

(1) *The cosmos could be/could have been a different shape—so there must be receptive void*. The Stoic cosmos is subject to periodic destruction by conflagration, during which the volume of matter is increased many fold.[12] So there exists at least some void outside of the cosmos. According to Simplicius, some Stoics employed Archytas' argument to show that the void must in fact be infinite (Hahn 1977, 106).

(2) *The possibility of motion of the entire world shows that there must be an infinite void.* This argument appears in Cleomedes:

> we can conceive the cosmos itself moving out of the place which it happens to occupy now. And together with its motion, we shall conceive the abandoned place as being empty and the place to which it is moved to be occupied and held by it. This latter place would be a filled void.[13]

Presumably we should add: But there is no limit to the direction, velocity, or duration of this movement, so we must conceive of the void as being infinitely extended in all directions.

---

[12] Thus, Cleomedes, believed to be early AD: "And if furthermore all substance is reduced to fire, as the most gifted physicists think, it must occupy a place more than ten thousand times as great, just like solid bodies when they are vaporised into smoke. So the place that is occupied by dissolved substance in the conflagration is now void, seeing that no body fills it"; quoted at Sorabji (1988, 129).

[13] Quoted at Sorabji (1988, 129 f). Cleomedes himself denied that the cosmos was in fact in motion; see the passage at Sambursky (1959, 143 f.). Achilles the Grammarian records the following Stoic argument "If the cosmos were moving down in an infinite void, rain would not overtake the earth. But it does. Therefore the cosmos does not move but stands still" (Hahm 1977, 109 f.). Some Stoics questioned the coherence of the notion of a moving cosmos (see Hahm 1977, 122).

Now this last argument is of fundamental importance. In Archytas' argument and in the argument from the conflagration, the existence of the void functions only as a sort of place-holder for possible deformations or expansions of the cosmos. But even if such a deformation or expansion were to take place, one would still be able to understand place and motion in broadly Aristotelian terms—place could be defined in terms of material extension, and motion in terms of relative motion, given some body truly at rest. But with Cleomedes' thought experiment regarding the possible motion of the cosmos as a whole this is no longer possible—the thought experiment is only coherent if the void itself plays a role in defining place and motion. Cleomedes wants us to judge that in the situation described the cosmos is moving through the void—because it successively occupies different parts of the void, rather than because of any characteristic relative motion between its parts.

This suggests that, for some Stoics at least, the void ought to be viewed as an infinite three-dimensional entity, whose parts maintain their identity over time and provide the ultimate grounding for the notions of place and motion.[14]

THE SCHOLASTICS. No brief summary can do justice to the full range of Scholastic mutations of Aristotelianism. From Edward Grant I take the following points.

(1) The Aristotelian account of place remained essentially unchallenged throughout the medieval period (Grant 1976, 154), despite active discussion of the paradoxes of motion and problems regarding the motion of cosmic sphere (1981b).

[14] This is the standard interpretation of the Stoic void, developed, e.g., in Hahm (1977, Chapter IV) and Sambursky (1959, Chapter IV). An alternative interpretation is argued for in Todd (1982) and Inwood (1991).

(2) There was a unanimous consensus among medieval scholastics that the cosmos could not be thought of as immersed in an extended, three-dimensional void (Grant 1981a, 180). Grant identifies a theological basis for this consensus, in scholastic reluctance to recognize any infinite being in addition to God.[15] In this context, Aristotle's complaint that if void could be occupied by body, then two things would be in the same place was widely accepted as a decisive argument (Grant 1969; 1981a, Chapters 1 and 2).

(3) This position seems entirely compatible with Scholastic use of arguments showing that the world could have been larger that it was, or differently shaped. Archytas' argument was communicated to the Scholastics in works of Simplicius, and was afterwards widely discussed (Grant 1981a, 106 f.). It was also noted that God could have chosen to create a larger world than he had (Grant 1981a, 137; see also Sorabji 1988, 129). But, of course, this is consistent with the insistence that the extra-cosmic void is not an extended entity.

(4) In 1277, theologians in Paris, fighting a rearguard action against Aristotelians in the faculty of arts, managed to have a number of propositions condemned by the Bishop of Paris. For a time, the teaching of these propositions was punishable by excommunication. Even after this penalty was lifted, the condemnation continued to have an effect: the condemned propositions continued to be eschewed by conscientious writers. Among the propositions condemned, we find the following.[16]

- "That there is no more excellent state than to study philosophy."
- "That the only wise men in the world are philosophers."
- "That one should not hold anything unless it is self-evident or can be manifested from self-evident principles."
- "That if the heaven stood still, fire would not burn flax because God would not exist."
- "That a sphere is the immediate efficient cause of all forms."

[15] This was not, however, viewed as problematic by early Christians; see Sambursky (1982, 14–17).

[16] These are propositions 1, 2, 4, 79, 81, 97, 149, 178, 203, 205, and 66 in the numbering and translation found in Lerner and Mahdi (1963, Selection 18).

- “That it pertains to the dignity of the higher cause to be able to commit errors and produce monsters unintentionally, since nature is able to do this.”
- “That the intellect of the dead Socrates does not have the science of those things of which it once had science.”
- “That by certain signs one knows men’s intentions and changes of intention, and whether these intentions are to be carried out, and that by means of these prefigurations one knows the arrival of strangers, the enslavement of men, the release of captives, and whether those who are coming are acquaintances of thieves.”
- “That one should not confess, except for the sake of appearance.”
- “That simple fornication, namely that of an unmarried man with an unmarried woman, is not a sin.”
- “That God could not move the heaven in a straight line, the reason being that He would then leave a vacuum.”

It has been argued that the inclusion of this last proposition had momentous consequences for the development of the concept of space—for in the 14th century one finds a number of Scholastics happy to say that God could move the cosmos through the void, or was faced with a choice about where in the void to create the cosmos (see Grant 1979 and Lindberg 1992, 233–244). It is difficult to see how the possibility of the translation of the world as a whole along a straight line can be underwritten by anything short of the an extended void whose parts maintain their identity through time, thus providing a standard of place and motion independent of body.

THE EARLY MODERNS ATOMISTS. Spurred in part by a flood of previously unavailable ancient texts, the 16th and 17th centuries saw a large number of non-Aristotelian accounts of place, space, void, motion, matter and the cosmos (see Koyré 1957 and Grant 1981a, Chapters 7 and 8). It is helpful to note here one particular strand of development which pre-figured—and indeed, directly influenced—Newton’s account absolute space: Gassendi’s attempt to revive and Christianize ancient atomism.

Gassendi self-consciously mines ancient and scholastic authors for arguments. His cosmology features a single material world, created by God and composed of atoms, immersed in an infinite three-dimensional void space, itself neither substance nor accident, and suffused with the omnipresence of God.[17] In Gassendi and/or his English disciple Charleton, we find the following arguments and claims. (1) The paradoxes of motion cause difficulties for any Aristotelian account of motion (Charleton 1966, 69). (2) The argument of Archytas for the existence of an infinite void (see Grant 1981a, 389 n. 168). (3) God could have created the universe larger than it is (Charleton 1966, 11), or could repeatedly annihilate the universe and created a larger version—so the void must be infinite (Brush (ed.) 1972, 387). (4) We can conceive God moving the material world from one location to another (Brush (ed.) 1972, 388; Charelton 1966, 67 f.).

***

Obviously this is only the tip of the iceberg. But I hope I have given some feeling for the wealth of interesting arguments and theses salient to the absolute-relational debate that pre-date Descartes, Newton, and Leibniz, but which reverberate through, e.g., Newton's *De Gravitatione* and through the Leibniz–Clarke correspondence. In closing, I would like to make some more speculative remarks about what *was* new in discussion of space and motion in the 17th century.

The new mathematical physics of the 17th century took over from astronomy the practice of representing the motions of bodies by curves in Euclidean space, parameterized by time. The course of the century saw a progressive widening of the scope and ambitions of this new physics, with its dynamical treatment of the motion of bodies: from its first specimens in Galileo's treatment of free fall and projectile motion near the Earth; to Descartes' qualitative modeling of the celestial motions via vortices; to the competing quantitative accounts of the system of the world offered by Newton and

[17] For references to others who rejected the substance-attribute dichotomy in the case of space, see Grant (1981a, 187, 199, 204, 217, 240, and 392 nn. 182 and 185).

the later vortex theorists (including Leibniz). The first half of the 17th century also saw the decisive rejection by astronomers and natural philosophers of Ptolemaic astronomy and the Aristotelian cosmology in which it was set. Of course, these two sets of developments were related to one another in many ways. I would like to emphasize just one aspect by claiming that the transition from Aristotelian cosmology to the new cosmologies of the 17th century undermined the most straightforward route to interpreting the geometrical curves in Euclidean space as representing the motions of bodies; and that the competing accounts of the nature of space, the nature of motion, and the relation between the two that one finds in Descartes, Newton, and Leibniz can be viewed as aspects of the process of recognition and resolution of this problem.

From Galileo onwards, the new mechanics was based on one form or another of the principle of inertia, according to which bodies free from interference naturally tend to trace out a certain sort of curve in space. The interpretation of curves in Euclidean space as representing the motion of bodies is unproblematic in contexts in which the motion of all bodies can be understood as motions relative to a natural reference body. For then, speaking anachronistically, one can regard the curves as describing motion in the space picked out by coordinate axes attached to the reference body. The location of a moving body relative to the fixed body is determined at each moment of time by the parameterization of the geometrical curve associated with the moving body.

In the mainstream cosmological tradition deriving from Aristotle and Ptolemy, the Earth is at rest at the center of a finite series of rotating material spheres which exhaust the contents of the universe (there is nothing—not even empty space—lies beyond the sphere of the fixed stars). In this context the Earth provides a geometrically privileged, fixed body—the natural reference body to which the complicated trajectories of Ptolemaic astronomy can be referred.

For Copernicus and Kepler, the cosmos is still spherical, and both the central sun and the outer surface which encloses the fixed stars are immobile, and are suitable to serve as reference bodies (Koyré 1957, 29–34, 76–87). According to Copernicus, the stars are fixed to the surface of the outermost sphere; according to Kepler they are scattered throughout a shell within the outermost sphere, with the shell enclosing a void in which the solar system is located. Copernicus is quite explicit: "the first and supreme of all is the sphere of the fixed stars which contains everything and itself and which, therefore, is at rest. Indeed, it is the place of the world to which are referred the motion and the position of all other stars" (quoted at Koyré 1957, 33; of course here the planets, including the earth, are numbered among the "other stars").

Galileo, on the other hand, is able to understand the curves that terrestrial bodies trace out in his mechanics as curves relative to the Earth, treated as fixed. But of course, he is also a partisan of the Copernican system, and maintains against Tycho Brahe and Ptolemy that the Earth rotates daily and moves through the heavens annually. And he can make sense of these claims, if he wishes—for like Copernicus and Kepler he maintains that "the fixed stars (which are so many suns) agree with our sun in enjoying perpetual rest" (1967, 327).[18]

[18] Galileo, while content to grant for the sake of argument that the cosmos is spherical in shape, he makes a point of noting that there is little evidence that the material universe is finite in extent (1967, 319 *f.*). And indeed, he appears to have been genuinely undecided on—and quite likely, not especially interested in—questions concerning the finitude or infinitude of the number of stars, and of the displacement of the stars in space (see Koyré 1957, 95–99).

But as the century progressed, new cosmologies emerged in which the Earth orbits the Sun along with the other planets, while the Sun itself is just another star, and the great multitude of stars is scattered haphazardly across space.

In this new context, the Earth no longer provides a natural reference body for the interpretation of the motion of bodies in terms of geometrical curves. Not only does the Earth itself move, but being banished from the center of the cosmos, it no longer able to claim privilege over any other body. Being motionless, the Sun is suited to serve the purpose—though, being banished from the center of the universe, it can no longer claim any privilege over the other stars. What is needed is an account of motion that refers motions to something other than body, or one which grapples directly with the fact that only some reference bodies are suitable to refer motions to (in the sense that the law of inertia does not hold if all motion is referred to a body in an arbitrary state of motion.

It was of course Newton who first saw clearly the difficulties involved. He showed that Descartes's analysis of motion in terms of the separation of contiguous bodies was unable to provide the conceptual scaffolding required to make sense of the principle of inertia and concluded that absolute space provided the best foundation for the new mathematical natural philosophy.[19]

But Kepler seems to have already sensed the difficulties that lay ahead—in rejecting the notion of an infinite material universe, he remarks that "This very cogitation carries with it I don't know what secret, hidden horror; indeed, one finds oneself wandering in this immensity, to which are denied limits and center and therefore also all determinate places" (quoted at Koyré 1957, 61).

[19] For Newton's treatment of Descartes's analysis of motion, see especially the passage on pp. 19–21 of Janiak (ed.) (2004). Spinoza appears to make a similar point in Corollary 3 to Proposition 22 in Part 2 of *The Principle of Cartesian Philosophy*.

References

Brush, S. (ed.) (1972). *The Selected Works of Pierre Gassendi*. New York: Johnson Reprint Corporation.

Burnyeat, M. (1997). "The Sceptic in His Place and Time", in M. Burnyeat and M. Frede (eds.) *The Original Sceptics: A Controversy*. Indianapolis: Hackett, 92–126.

Charleton, W. (1966). *Physiologia Epicuro-Gassendo-Charltoniana*. New York: Johnson Reprint Corporation.

Furley, D. (1987). *The Greek Cosmologists*. *Volume 1: The Formation of the Atomic Theory and its Earliest Critics*. Cambridge: Cambridge University Press.

Galilei, G. (1967) *Dialogue Concerning the Two Chief World Systems*. Los Angeles: University of California Press.

Grant, E. (1969). "Medieval and Seventeenth-Century Conceptions of Infinite Void Space Beyond the Cosmos", *Isis* 60: 39–60.

Grant, E. (1976). "Place and Space in Medieval Physical Thought", in P. Machamer and R. Turnbull (eds.), *Motion and Time, Space and Matter*. Columbus: Ohio State University Press, 137–167.

Grant, E. (1979). "The Condemnation of 1277, God's Absolute Power, and Physical Thought in the Late Middle Ages", *Viator* 10: 211–249.

Grant, E. (1981a). *Much Ado About Nothing: Theories of Space and Vacuum from the Middle Ages to the Scientific Revolution*. Cambridge: Cambridge University Press.

Grant, E. (1981b). "The Medieval Doctrine of Place: Some Fundamental Problems and Solutions", in A. Maier and A. Paravincini Bagliani (eds.), *Studi Sul XIV Secolo in Memoria de Anneliese Maier*. Rome: Edizioni di Storia e Letteratura, 57–79.

Hahm, D. (1977). *The Origins of Stoic Cosmology*. Columbus: Ohio State University Press.

Inwood, B. (1991). "Chrysippus on Extension and the Void", *Revue Internationale de Philosophie* 45: 245–266.

Inwood, B. and L. Gerson (eds.) (1994). *The Epicurus Reader*. Indianapolis: Hackett.

Janiak, A. (ed.) (2004). *Isaac Newton: Philosophical Writings*. Cambridge: Cambridge University Press.

Koyré, A. (1957). *From the Closed World to the Infinite Universe*. Baltimore: The Johns Hopkins University Press.

Lerner, R. and M. Mahdi (eds.) (1963). *Medieval Political Philosophy: A Source Book*. Cornell University Press.

Lindberg, D. (1992). *The Beginnings of Western Science*. Chicago: University of Chicago Press.

Mckeon, R. (ed.) (1941). *The Basic Works of Aristotle*. New York: Random House.

Melville, R. (trans.) (1997). *Lucretius: On the Nature of the Universe*. Oxford: Oxford University Press.

Sambursky, S. (1959). *Physics of the Stoics*. New York: Macmillan.

Sambursky, S. (1982). *The Concept of Place in Late Neoplatonism*. Jerusalem: The Israel Academy of Sciences and Humanities.

Sorabji, R. (1988). *Matter, Space, and Motion: Theories in Antiquity and their Sequel*. London: Duckworth.

Todd, R. (1982). “Cleomedes and the Stoic Concept of the Void”, *Apeiron* 16: 129–136.

Westfall, R. (1962). “The Foundations of Newton’s Philosophy of Nature”, *British Journal for the History of Science*, 1: 171–182.